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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF ANIMAL INDUSTRY.—BULLETIN 148.

A. D. MELVIN, CHIEF OF BUREAU.

THE MANUFACTURE OF BUTTER FOR STORAGE.

BY

L. A. ROGERS, S. C. THOMPSON,
AND J. R. KEITHLEY,
Of the Dairy Division.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Animal Industry,
Washington, D. C., July 23, 1912.

Sir: I have the honor to transmit herewith a manuscript entitled "The Manufacture of Butter for Storage," by Messrs. L. A. Rogers, S. C. Thompson, and J. R. Keithley, of the Dairy Division of this bureau. The paper describes the results of three seasons' storage of butter made and packed for the United States Navy under the supervision of the bureau and two seasons' work with other butter manufactured under commercial conditions, so as to test thoroughly the effect of storage at various temperatures upon the quality of butter made by different methods. The superiority of butter made from pasteurized sweet cream is again demonstrated.

This paper deals only with the keeping and commercial qualities of the butter. Besides advantages in this respect, however, pasteurization also serves as a protection to the health of the consumer by destroying pathogenic bacteria, such as those of tuberculosis and typhoid fever, which are known to survive for long periods in butter made from unpasteurized cream.

As the commercial storage of butter is of great economic importance to the trade and to consumers, I respectfully recommend that the results of this work be published as a bulletin of this bureau.

Acknowledgment is made for assistance rendered by the Fox River Butter Co., the Morton Creamery, the Steele Center Creamery, the Biscay Creamery, and the Hutchinson Cooperative Creamery.

Respectfully,

A. D. Melvin,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

	Page.
Introduction	7
Relation of acidity of cream to keeping quality of butter	8
Butter for the use of the Navy	10
Comparison of Navy butter made from sweet and from ripened cream	13
Butter made for storage by different methods	14
Experiments of 1910	14
Experiments of 1911	18
The influence of storage temperature on changes in butter	25

ILLUSTRATIONS.

	Page.
FIG. 1. Diagram showing relation of acidity of cream to keeping quality of butter	9
2. Distribution of butter scores before and after storage—Raw-cream butter	23
3. Distribution of butter scores before and after storage—Pasteurized ripened-cream butter	23
4. Distribution of butter scores before and after storage—Pasteurized unripened-cream butter	24
5. Changes in butter scores after storage at various temperatures	26

THE MANUFACTURE OF BUTTER FOR STORAGE.

INTRODUCTION.

In this country the long annual period of low production of butter has made it necessary, in order to insure a fairly uniform supply, to store large quantities during the short season when the production exceeds the demand. In the spring and early summer months the quantity of butter produced is in excess of the demand. This season is followed by a few months in which the supply and the demand are nearly equal, and this in turn by a long period covering the winter months in which the supply of fresh butter is considerably less than the demand. In May, June, and the early part of July, when the supply of fresh butter is large and the quality is good, there is active buying for storage. There may be some butter put in storage later in the summer if the production holds up, but this is usually for the purpose of disposing of a temporary and perhaps local oversupply, and little butter is bought for the express purpose of holding for the winter trade.

As the supply of fresh butter diminishes the storage stock is drawn upon to meet the shortage, and by the end of March or early in April, when the supply of fresh butter begins to increase again, the storage stock is nearly or completely exhausted. Butter may therefore be held in storage from May to April, a period of 11 months, although the average time is probably 2 or 3 months less. Under exceptional conditions dealers may have butter left in storage over one year, but this is usually done at a heavy loss.

The development of mechanical refrigeration has been followed by a rapid increase in storage facilities and a high state of perfection in the methods of holding the large rooms at a low temperature. An insignificant quantity of butter is held in small towns in refrigerators mainly by an ice-salt system at 20° to 25° F., but the bulk of storage butter is in the great trade centers in large warehouses at temperatures of 0° F. and below. This low temperature is usually maintained by circulating brine in coils on the walls of the butter rooms, although in some warehouses air is cooled to the desired temperature in bunker rooms and circulated through the storage rooms by fans.

In a recent book [1] the statement is made that "modern butter storage rooms are kept below 0° F.; the butter is quite unchanged on

[1] Marshall, Charles E., editor. Microbiology. Philadelphia, 1911.

removal from storage * * * ." The latter part of this statement is, however, entirely at variance with the usual experience of dealers who store butter, as well as those who have investigated storage problems. All butter changes slowly in storage, even at temperatures as low as —10° F. There is an alteration in the physical condition, the waxy texture of the fresh butter changing to a pasty consistency. This is not evident, however, except on very long storage, and is not a factor in commercial storage. The most evident alteration is in the flavor, which may change so much that the value of the butter is seriously affected. The nature of this change is not determined by the temperature of storage, since all flavors which occur in cold storage butter are also found in butter held at higher temperatures. The most common one is the so-called "storage flavor," which appears only in old butter, although in this sense butter may become old in two or three weeks. Another flavor which is a source of great trouble in butter of this class is the peculiar condition known as "fishy" flavor. This is especially objectionable because it may occur in butter which was originally of the highest quality and because its presence materially lessens the market value of the butter.

The exact cause of these flavors has not been determined with any certainty, but certain factors which may influence or accelerate their development have been pointed out in previous publications of the Dairy Division.[1,2]

RELATION OF ACIDITY OF CREAM TO KEEPING QUALITY OF BUTTER.

The importance of the acidity of the cream at the time of churning and the possibility of making butter of superior keeping quality by limiting the acidity has been especially emphasized in these publications. It was shown that butter made from unripened pasteurized cream changed very little in storage, while butter made from the same cream after the usual ripening invariably went off flavor. It was also observed that while fishiness frequently developed in the ripened-cream butter, authentic cases never occurred in the butter made from sweet cream. In a tabulation of the examination of 259 samples of experimental butter from cream of known acidity, of 137 samples from cream having an acidity below 0.3 per cent, only 2, or 1.5 per cent, were marked "fishy," while of 122 samples having an acidity of 0.3 per cent or over, 60, or 49.2 per cent, were fishy. However, in all results which are dependent on the sense of taste allowance should be made for differences of opinion and in the conception of the flavor associated with any particular designation.

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[1] Rogers, L. A., and Gray, C. E. The influence of acidity of cream on the flavor of butter. U. S. Department of Agriculture, Bureau of Animal Industry, Bulletin 114. Washington, 1909.

[2] Rogers, L. A. Fishy flavor in butter. U. S. Department of Agriculture, Bureau of Animal Industry, Circular 146. Washington, 1909.

The relation of the acidity of the cream to the progressive change in flavor is illustrated by figure 1, which shows the scores of various lots of experimental butter made from pasteurized cream, arranged in the order of the acidity of the cream at time of churning. Lot 19, in which no acidity is given, was made from overripe hand-separator cream. In some cases two lots of butter with different acidities were made from the same lot of cream. This was true of samples 13 and 14, 15 and 16, 17 and 18, 21 and 22, 23 and 24, and 25 and 26.

It will be noticed that the score of butter made from cream with an acidity below 0.3 per cent ranged, with two exceptions, above 90.

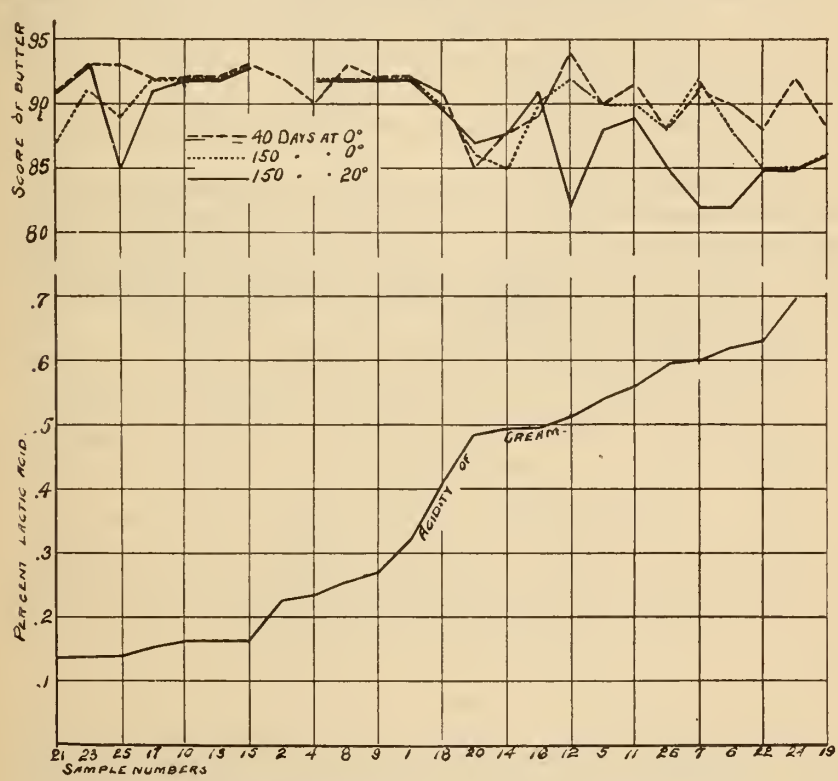

FIG. 1.—Diagram showing relation of acidity of cream to keeping quality of butter.

On the other hand, the score of the butter made from cream with the customary acidity was variable and usually below 90. This was especially true of the samples stored at 20° F., which would be expected to bring out more strongly the tendency of the butter to deteriorate.

The probable nature of the relation of acidity to change in flavor has been discussed in previous bulletins of this bureau and need not be taken up here. It is evident, however, that to make butter of good keeping quality any treatment that increases the chemical instability of the product should be avoided. Butter of good quality can be made from sweet pasteurized cream and the deteriorating influence of the acid thus eliminated.

BUTTER FOR THE USE OF THE NAVY.

Advantage has been taken by the Navy Department of the fact just stated, that department having found it expedient for several years to procure and store a year's supply of butter during the period of heavy production. This practice has enabled that department to secure butter of high quality at a minimum price. The butter has been made from pasteurized sweet cream and packed in hermetically sealed tin cans under the supervision of and according to specifications prepared by the Dairy Division, Bureau of Animal Industry, Department of Agriculture. It has shown such excellent keeping quality in storage and has given such uniform satisfaction for the past three years that the method used in its manufacture has proved a desirable and proper one.

The specifications covering the manufacture of this butter contain the following requirements:

1. *Butter.*—Shall be fresh butter made during such period of 90 days after April 15 and before August 15 as shall be most suitable for butter making in the locality of the creamery where it is to be made; from pasteurized milk or cream, none of which shall contain before pasteurization more acid in 50 c. c. than will be neutralized by 15 c. c. or 13 c. c. of tenth-normal alkali solution, as determined by Mann's acid test, for butter scoring 94 and 95, respectively.

2. *Quality.*—Shall be strictly of the grade of creamery "extras" and one-third must score not less than 94 and two-thirds not less than 95 at the time of packing.

3. *Composition.*—Moisture in the butter must not exceed 13 per cent. There must be no preservative used other than common salt, and that shall be at a rate giving not less than 2½ per cent nor more than 3¼ per cent in the butter at the time of packing.

4. *Packing.*—The butter must be packed in tins and the tins fully sealed at the creamery where the butter is made and within 12 hours after the time of churning.

5. *Inspection.*—The ingredients, manufacture, sanitation, packing, boxing, marking, and shipping of the butter shall be subject to inspection by Government inspectors, who shall have full authority to reject any lot of milk, cream, or the finished butter, or any other requirement which does not conform in every respect to the specifications.

6. *Storage.*—All butter must be kept at a temperature below 50° F. after being packed and until placed in cold storage. It shall be forwarded as rapidly as carload lots are accumulated in the packing plant to such warehouse as may be designated by the Bureau of Supplies and Accounts, Navy Department, where the butter will be held at zero or lower temperature.

The Navy Department has stored during the past three years 2,084,022 pounds of butter, all of which was made according to these specifications, except where occasional churnings were made from ripened cream for experimental purposes and at one creamery which had a special contract.

During the packing seasons of 1909 and 1910 a sample can of butter was set aside from each churning, and in 1911 a similar sample was taken from each day's make. These samples were handled and stored in the same way as the other butter and kept in storage for a period averaging 8 months, at the end of which time they were

examined to determine the quality and the amount of deterioration that had taken place.

Tables 1, 2, and 3 contain the data for Navy butter for the years 1909, 1910, and 1911, respectively, showing the amount packed by each creamery, the original average score, the average score after being stored, and the points lost in storage. These are summarized in Table 4, which shows the annual averages.

TABLE 1.—*Comparative deterioration in storage of Navy butter packed in 1909.*

Creamery No.	Amount packed.	Original score.	Score after storing.	Points lost in storage.
	Pounds.			
1.....	144,000	94	91.35	2.65
2.....	100,008	95	89.49	5.51
3.....	270,000	95	91.41	3.59
4.....	220,014	95.5	91.23	4.27
5.....	36,000	94.2	87.25	6.95

Part of the butter was examined February 5 to 10, 1910, by H. J. Credicott, Federal butter inspector on the Chicago market; W. C. Fryhofer, Federal butter inspector on the New York market; and C. W. Larson, assistant professor of dairying, Pennsylvania State College. The remainder was scored March 1 to 4, 1910, by C. W. Larson, J. C. Joslin, Federal creamery instructor for Minnesota, and Robert McAdam, field inspector of the Dairy Division.

TABLE 2.—*Comparative deterioration in storage of Navy butter packed in 1910.*

Creamery No.	Amount packed.	Original score.	Score after storing.	Points lost in storage.
	Pounds.			
6	108,000	94.69	92.33	2.36
7	54,000	95.00	92.14	2.86
8	54,000	95.00	92.02	2.98
9	108,000	94.01	91.90	2.11
10	108,000	94.76	91.64	3.12
11	162,000	95.00	91.43	3.57
12	108,000	94.76	91.27	3.49

These samples were scored February 28 to March 3, 1911, by C. W. Fryhofer, Federal butter inspector on the New York market; Robert McAdam, field inspector of the Dairy Division; and O. A. Storvick, Federal creamery instructor for Minnesota.

TABLE 3.—*Comparative deterioration in storage of Navy butter packed in 1911.*

Creamery No.	Amount packed.	Original score.	Score after storing.	Points lost in storage.
	Pounds.			
13	162,000	94.92	92.72	2.20
14	72,000	95.00	92.68	2.32
15	108,000	94.53	92.57	1.96
16	162,000	94.67	92.51	2.16
17	108,000	94.67	91.24	3.43

These samples were scored February 13 to 15, 1912, by J. C. Joslin, Federal butter inspector on the Chicago market; Robert McAdam, field inspector of the Dairy Division; and Thomas Corneliuson, assistant in dairy manufacturing investigations, of the Dairy Division.

TABLE 4.—*Showing the average yearly scores, before and after storage of all Navy butter for 1909, 1910, and 1911.*

Year.	Average original score.	Average score after storing.	Average points lost in storage.
1909	94.92	90.90	4.02
1910	94.73	91.75	2.98
1911	94.75	92.37	2.38

A comparison of these results shows that the average score at the time of packing has remained nearly uniform, while the average score after storing has gradually increased from 90.90 in 1909 to 92.37 in 1911, with a corresponding decrease in the deterioration in storage from 4.02 to 2.38 points.

TABLE 5.—*Average scores when removed from storage of Navy butter for 3-year period, arranged according to months in which packed.*

Year and creamery.	Month in which butter was packed.						Date of scoring.
	April.	May.	June.	July.	August.	September.	
1909:							
1	.....	91.60	91.42	91.37	91.19	[1] 92.14	February and March, 1910.
2	.....	89.56	89.40	90.88	.....	.....	Do.
3	91.71	91.33	91.05	.....	.....	.....	Do.
4	.....	90.40	91.35	91.62	90.63	[1] 91.28	Do.
5	.....	.....	86.30	88.40	.....	.....	Do.
1910:							
6	.....	.....	92.75	91.64	.....	.....	March, 1911.
7	.....	92.50	92.34	91.79	92.12	.....	Do.
8	.....	92.50	91.94	.....	.....	.....	Do.
9	.....	91.50	91.35	91.56	92.37	.....	Do.
10	.....	91.04	91.95	91.80	.....	.....	Do.
11	90.45	92.41	.....	.....	.....	.....	Do.
12	.....	91.25	91.37	.....	.....	.....	Do.
1911:							
13	.....	92.30	93.35	92.47	.....	.....	February, 1912.
14	92.66	.....	.....	.....	.....	.....	Do.
15	.....	.....	92.03	92.63	93.00	.....	Do.
16	.....	.....	92.59	92.60	92.30	.....	Do.
17	.....	92.23	92.00	89.93	91.60	.....	Do.
Average..	91.60	91.52	91.41	91.39	91.88	91.71	

[1] Time extended beyond Aug. 15 by the Navy Department.

The above table shows that there was little variation in the keeping quality of the butter made in different months during the storage period, also that the butter in storage 11 months varied but little in quality from that stored 5 months.

Creamery No. 5 was permitted, by special contract, to disregard the acidity and pasteurization requirements of the specifications and

to increase the water content to 15.5 per cent on a guaranty that the butter would score 90 after being held in storage for 8 months. This butter was made from unpasteurized cream, practically one half of which was from whole milk delivered daily, and the other half from gathered cream delivered every other day. Twelve per cent starter was used and acidity of about 0.56 per cent was developed. The cream was then cooled to 48°–50° F. and held until 4 o'clock the next morning, when it was churned. The methods of packing, shipping, and storing were the same as at other creameries having contracts for Navy butter.

COMPARISON OF THE BUTTER MADE FROM SWEET AND FROM RIPENED CREAM.

Tables 6 and 7 show the scores of each churning made at creameries Nos. 5 and 6, respectively. These tables are given so that the deterioration in storage of butter made from unpasteurized ripened cream may be compared with that made from pasteurized sweet cream. Creamery No. 6 was selected for this comparison because it represents average conditions and also because a few experimental churnings, as noted in the table, were made from ripened cream.

TABLE 6.—*Scores before and after storage of Navy butter made at creamery No. 5 from unpasteurized ripened cream.*

Date of churning.	Original score.	Score after 8 months' storage.	Date of churning.	Original score.	Score after 8 months' storage.
1909.			1909.		
June 1	94.00	86.00	June 27	94.00	87.50
June 2	94.00	87.00	July 1	94.00	89.00
June 3	94.00	86.00	July 3	94.00	88.00
June 4	94.00	87.00	July 5	95.00	87.00
June 5	94.00	88.50	July 7	94.00	90.00
June 6	95.00	87.00	July 9	94.00	88.00
June 7	94.00	86.00	July 11	94.00	89.00
June 9	94.50	86.00	July 13	94.00	90.00
June 10	95.00	86.00	July 15	94.00	90.00
June 11	94.50	84.00	July 17	94.00	89.00
June 12	94.00	87.00	July 19	94.00	90.00
June 14	95.00	88.50	July 21	94.00	87.00
June 15	94.00	88.50	July 23	94.00	88.00
June 16	94.50	88.00	July 24	94.00	88.00
June 17	94.50	87.00	July 25	94.00	87.00
June 18	95.00	86.00	July 27	94.00	88.00
June 19	94.50	86.00	July 29	94.00	88.00
June 21	96.00	84.00	July 29	94.00	90.00
June 22	94.00	84.00	July 31	94.00	88.00
June 23	94.00	86.00	August 1	94.00	87.00
June 24	94.00	85.00			
June 25	94.00	84.00	Average	94.20	87.25
June 26	94.00	86.00			

It will be seen that the average score of the butter at packing was 94.20, while the average score at the end of 8 months was but 87.25, showing a deterioration of 6.95 points in storage.

The judges found 90.7 per cent of all the samples showing a pronounced fishy flavor.

TABLE 7.—*Scores before and after storage of Navy butter made at creamery No. 6 from pasteurized sweet cream.*

Date of churning.	Original score.	Score after 8 months' storage.	Date of churning.	Original score.	Score after 8 months' storage.
1910.			1910.		
June 2	95.00	91.50	June 27	95.00	92.50
June 3	95.00	92.50	June 28	94.00	92.00
June 4	95.00	93.50	June 29	95.00	92.50
June 5	95.00	93.50	June 30	95.00	91.50
June 6	95.00	93.50	June 30	95.00	92.50
June 7	95.00	94.00	July 2	94.00	92.50
June 8	95.00	93.00	July 3	94.00	93.50
June 9	95.00	93.00	July 5	94.00	92.00
June 10	95.00	92.50	July 6	94.00	93.00
June 11	95.00	92.50	July 1	94.00	92.50
June 12	95.00	91.50	July 7	94.00	93.00
June 13	95.00	92.00	July 8	94.00	[1] 90.50
June 14	95.00	92.00	July 9	94.00	93.50
June 15	95.00	93.50	July 9	94.00	[1] 89.00
June 16	95.00	93.50	July 10	94.00	91.50
June 17	95.00	92.00	July 11	94.00	90.50
June 18	95.00	92.50	July 12	94.00	90.00
June 19	95.00	93.00	July 12	94.00	90.00
June 20	95.00	93.00	July 13	94.00	92.50
June 21	95.00	94.00	July 13	94.00	92.50
June 22	95.00	93.00	July 14	94.00	92.00
June 23	95.00	94.50	July 14	94.00	93.00
June 24	95.00	92.00	July 14	94.00	[1] 88.00
June 25	95.00	93.00			
June 26	95.00	92.50	Average	94.69	92.33

[1] This butter made from ripened cream.

The average score at the time of packing was 94.69 and the average score at the end of 8 months was 92.33, showing a deterioration of 2.36 points in storage. The judges scored but two samples below 90 points, both of which came from the experimental churnings of ripened cream, one of which was pronounced fishy.

A comparison of Tables 6 and 7 shows a difference of only 0.49 points in the score at the time of packing, while after being held in storage the difference amounts to 5.08 points in favor of the butter made from pasteurized sweet cream.

BUTTER MADE FOR STORAGE BY DIFFERENT METHODS.

EXPERIMENTS OF 1910.

In order to demonstrate the feasibility of butter dealers having butter made expressly for storage, arrangement was made in 1910 with three creameries in the vicinity of Owatonna, Minn., to make butter in accordance with our directions. One of these, which we will designate as creamery A, made butter from unpasteurized ripened cream. Another, creamery B, pasteurized the cream, added a starter, and ripened the cream in the usual way. The third, creamery C, pasteurized the cream, cooled it at once, and churned on the afternoon of the day the cream was received without the addition of starter. Brief records of the processes were made by the butter makers, but for the sake of brevity these are omitted. These creameries were of the cooperative type, receiving whole milk or sweet hand-separator cream, and were selected on account of the standing of the butter makers and

the reputation of the product. With the exception of one visit to get the work started and another when it was nearly finished, the butter makers had no supervision. The entire output of the three creameries during the experimental period was purchased by a wholesale butter house. One tub from each churning was scored when received in Chicago by the scorer of the butter company and Mr. Joslin, of the Dairy Division. One tub from each churning was stored in the Dairy Division rooms at 0° F., one at 10°, and from most of the churnings an additional tub at 20°. This butter was packed in June and the early part of July, and was removed from storage in February, 1911, and scored by the same scorers who had scored it before storage. The results of the scorings, with the comments of the scorers, are given in Tables 8, 9, and 10, and the results for the three creameries are summarized in Table 11.

TABLE 8.—*Scores before and after storage of butter made from ripened raw cream—Creamery A.*

Churning No.	Score of fresh butter.	Comments.	Storage temperature.	Score after storage.	Comments.
			° F.		
A 8	92	Unclean, oily	0	88	Storage, unclean, will go fishy.
			10	89	Strong storage.
			20	88	Storage.
9	93	Trifle oily	0	87	On fishy order, storage.
			10	87	On fishy order.
			20	86	Fishy.
10	91	Curdy, salt coarse	0	85	Very fishy.
			10	86	Fishy and storage.
			20	86	Fishy.
11	93½		0	87	Unclean, storage, on fishy order.
			10	90	Storage.
			20	90	Storage, unclean.
12	91	Aroma tainted	0	89	Storage.
			10	87	Unclean, storage.
			20	87	Storage.
13	92	Overworked	0	85	Fishy.
			10	86	Storage, fishy.
			20	85	Fishy.
14	93½	Sour, cheesy	0	87	Storage, on fishy order.
			10	87	Do.
15	93	Sour, unclean	0	88	Unclean, storage, fishy order.
			10	85	Fishy.
16	93	do	0	89	Storage.
			10	88	Do.
17	92½	Trifle unclean, sour	0	87	Unclean, storage.
			10	88	Storage.
18	92	Sour, metallic, unclean	0	86	Stale, storage.
			10	86	Storage, unclean, fishy order.
19	90	Sour, unclean, oily, metallic	0	87	Storage, on fishy order.
			10	87	Strong storage, fishy.
20	93	Greasy, little coarse	0	87	Unclean, storage, may go fishy.
			10	85	Fishy.
			20	87	Storage.
21	93½	Good butter	0	86	Fishy.
			10	85	Do.
			20	85	Do.
22	92	Unclean aroma, heated, poor milk.	0	88	Unclean, storage.
			10	86	Fishy, metallic.
			20	85	Fishy.
23	92½	Trifle unclean	0	89	Storage.
			10	88	Strong storage, on fishy order.
			20	86	Fishy.
24	92	Unclean, poor cream	0	88	Storage, unclean.
			10	87	Storage.
			20	86	Fishy, storage.
25	92½	Sour and coarse	0	89	Strong storage.
			10	88	Very strong storage.
			20	85	Very fishy.

TABLE 9.—*Scores before and after storage of butter made from pasteurized ripened cream—Creamery B.*

Churning No.	Score of fresh butter.	Comments.	Storage temperature.	Score after storage.	Comments.
			°F.		
B 1	93	Oily	0	90	Strong storage.
			10	90	Do.
			20	90	Do.
2	93½	Sour	0	87	Storage, on fishy order.
			10	86	Storage, fishy.
			20	86	Do.
3	93½	Sour, wavy	0	89	Storage, on fishy order.
			10	92	Trifle storage.
			20	89	Strong storage.
4	93½	Wavy	0	90	Slight storage.
			10	91	Storage.
			20	89	Strong storage.
5	93	Wavy	0	89	Do.
			10	88	Storage and fishy.
			20	90	Strong storage.
6	92½	Sour, wavy	0	91	Slight storage and curdy.
			10	90	Unclean, slight storage, sour.
			20	88	Strong storage, stale.
7	94	Fine, trifle curdy	0	92	Trifle storage.
			10	92	Slight storage.
			20	88	Strong storage, on fishy order.
8	94		0	91	Slight storage.
			10	89	Storage, on fishy order.
			20	86	Strong storage, fishy.
9	93	Oily, weak body	0	88	Storage, on fishy order.
			10	88	Strong storage, may go fishy.
10	93½		0	92	Slight storage.
			10	91	Strong storage.
11	92½	Weak body	0	92	Slight storage, trifle unclean.
			10	89	Strong storage, unclean.
13	93½		0	89	Strong storage.
			10	88	Storage, on fishy order.
14	93		0	90	Storage.
			10	88	Storage, on fishy order.
15	94		0	92½	Slight storage, clean.
			10	92½	Trifle storage.
			20	92	Slight storage.
16	93	Oily	0	92½	Do.
			10	92	Slight storage, but sweet.
			20	86	Storage, fishy.
17	93	Oily	0	90	Storage, not unclean.
			10	89	Strong storage.
			20	89	Unclean, storage.
18	94		0	93	Good butter, slight storage.
			10	90	Storage and slight fishy.
			20	88	Storage, on fishy order.
19	94½		0	90	Strong storage.
			10	91	Storage.
			20	88	Strong storage.
20	94½		0	93	Good butter, slight storage.
			10	92	Storage.
			20	89	Storage, may get fishy.
21	93	Trifle coarse	0	92	Storage, otherwise good.
			10	92	Slight storage.
			20	90	Do.
22	94½		0	92	Do.
			10	93	Good butter, trifle storage.
			20	88	Storage, on fishy order.
23	94		0	92	Storage, but sweet.
			10	90	Storage.
			20	88	Storage, on fishy order.
28	93	Little sour and greasy, may go fishy.	0	92½	Trifle storage.
			10	90	Storage.
29	93	Little sour and greasy	0	92	Storage, otherwise good.
			10	86	Storage and fishy.
30	92½	Trifle unclean, poor material	0	90	Storage and unclean.
			10	89	Trifle unclean and slight storage.
31	93½	Good butter, little coarse	0	93½	Good butter, slight storage.
			10	92½	Trifle storage.
32	93	Sour, high acid	0	93½	Fine butter, trifle storage.
			10	93	Trifle storage, fairly good.
33	93½	Good butter, a little coarse	0	91	Slight storage.
			10	92	Do.
34	92½	Trifle unclean and flat	0	93½	Good butter, slight storage.
			10	90	Storage.
35	92½	Mottled	0	93	Trifle storage, good butter.
			10	92½	Trifle storage.

TABLE 10.—*Scores before and after storage of butter made from pasteurized unripened cream—Creamery C.*

Churning No.	Score of fresh butter.	Comments.	Storage temperature.	Score after storage.	Comments.
			°F.		
C 1	92	Flat, trifle unclean	0	93	Flat but good.
			10	93	Cooked but clean and sweet.
			20	92½	Good butter, flat.
2	92	Metallic	0	93	Flat but sweet.
			10	92	Trifle unclean.
			20	92	Unclean.
3	92	Greasy, will go fishy	0	93	Clean but flat.
			10	92	Slight storage unclean.
			20	92½	
4	93	Greasy	0	93	Good butter.
			10	92	Trifle cooked flavor.
			20	92½	Good butter, greasy.
5	91	Metallic, pasty	0	93	Good butter.
			10	92	Metallic.
			20	93½	Good butter, trifle metallic.
6	93	Slightly greasy	0	93	Clean and sweet.
			10	93	Clean but flat.
7	93½	.....do	0	93	Clean and sweet.
			10	93	Good butter.
8	93	.....do	0	93	Sweet good butter.
			10	93	Clean and sweet.
9	93	Clean but lacks character	0	92	Trifle unclean.
			10	90	Unclean.
			20	90	Do.
10		.....do	0	92	Cleans up sweet but flat.
			10	92	Not quite so good, but clean, oily.
			20	92	Trifle unclean.
11	93	.....do	0	93	Clean and sweet.
			10	93	Do.
			20	93	Clean but greasy.
12	93	Metallic	0	89	Unclean.
			10	91	Do.
13	93½	Greasy	0	93	Good butter.
			10	92½	Aroma not clean, otherwise good.
14	93	Metallic and unclean	0	91	Trifle unclean.
			10	92	Do.
			0	92½	Trifle storage, otherwise good.
15	93½	Sour, unclean	10	90½	Storage.
			20	91	Do.
			0	93	Slight storage, otherwise good.
16	94		10	88	Storage, on fishy order.
			20	89	Storage.
			0	90	Strong storage but clean.
17	94	Good butter	10	93	Good butter, slight storage.
			20	91	Slight storage.
			0	93	Sour but good, slight storage.
18	93½	Sour	10	92½	Slight storage.
			20	88	Strong storage, on fishy order.

TABLE 11.—*Average scores of Tables 8, 9, and 10—Creameries A, B, and C.*

Character of cream.	Number of churnings.	Average score of fresh butter.	Storage temperature.	Number of tubs scored.	Average score after storage.
			°F.		
Raw ripened cream	18	92.33	0	18	87.33
			10	18	86.94
			20	12	86.33
Pasteurized ripened cream	30	93.35	0	30	91.20
			10	30	90.28
			20	17	88.47
Pasteurized unripened cream	[1] 17	92.94	0	18	92.36
			10	18	91.91
			20	12	91.41

[1] Not including one churning which was not scored before storage.

While it is unsafe to make a too direct comparison from the data in the preceding tables, owing to the fact that the three kinds of butter were made in different creameries and from different lots of cream, nevertheless the superior keeping quality of the butter made from pasteurized sweet cream is obvious. The almost uniform occurrence of storage and fishy flavors in the ripened-cream butter and the absence of these flavors in the sweet-cream butter should not be overlooked.

EXPERIMENTS OF 1911.

In the following season (1911) a similar arrangement was made with the same company and butter was made for storage at two creameries. One of these, creamery E, pasteurized the cream and ripened it in the usual manner. The other divided the cream, adding a starter and ripening one-half without pasteurization, while the other half was pasteurized, cooled at once, and held until the following morning. We recommend that sweet cream be churned on the day of separation, not only to avoid the danger of development of bacteria in the cream on standing, but also on account of the economy of time and refrigeration. However, in this case, it was not practicable to arrange the churnings in this way. One of the writers divided his time between the two creameries, supervising the churning records, which are summarized in Tables 12, 13, and 14.

TABLE 12.—*Churning data for raw ripened cream—Creamery D.*

Churning No.	Fat in cream.	Churning temperature.	Acidity of cream as lactic acid.	Time required for churning.	Fat in buttermilk.	Water in butter.
	Per cent.	*°F.*	*Per cent.*	*Minutes.*	*Per cent.*	*Per cent.*
1	27.00	51.5	0.58	42	0.200	14.0
2	32.00	53.0	.55	24	.200	15.3
3	30.00	52.0	.56	35	.120	14.0
4	30.00	52.0	.53	31	.145	14.2
5	.....	51.0	.51	27	.240	15.0
6	34.00	53.0	.48	50	.175	15.0
7	34.00	53.0	.51	24	.190	15.0
8	35.25	52.0	.50	40	.090	.....
9	31.00	54.0	.53	36	.160	14.5
10	28.00	53.5	.56	45	.170	15.0
11	22.00	53.5	.55	26	.260	15.6
12	32.50	55.0	.55	25	.130	15.3
13	27.50	53.0	.52	43	.175	15.3
14	27.00	53.0	.51	33	.115	15.0
15	.....	52.0	.51	35	.105	14.8
16	31.50	52.0	.54	51	.175	15.9
17	28.00	53.0	.58	20	.260	15.8
18	29.00	51.0	.54	38	.190	14.1
19	33.50	50.0	.52	.....	.135	16.0
20	32.50	54.0	.54	60	.090	14.8
21	35.50	52.0	.50	83	.145	15.5
Average	30.50	52.5	.53	36.6	.165	15.0

TABLE 13.—*Churning data for pasteurized ripened cream—Creamery E.*

Churning No.	Fat in cream.	Churning temperature.	Acidity of cream as lactic acid.	Time required for churning.	Fat in buttermilk.	Water in butter.
	Per cent.	*°F.*	*Per cent.*	*Minutes.*	*Per cent.*	*Per cent.*
1	.....	51	0.56	35	0.070	14.3
2	.....	.....	.62	45	.....	13.8
3	.....	51	.58	35	.....	14.3
4	.....	50	.57	37	.120	14.6
5	.....	51	.58	40	.....	13.8
6	.....	50	.56	45	.....	14.0
7	.....	50	.54	50	.420	.....
8	36.00	52	.53	40	.170	14.0
9	40.00	51	.54	35	.180	14.3
10	30.00	51	.58	45	.110	13.5
11	34.50	51	.56	40	.190	14.1
12	34.50	50	.56	35	.140	13.1
13	.....	50	.54	35	.....	14.1
14	33.00	51	.55	45	.140	13.7
15	.....	50	.54	40	.250	14.1
16	32.50	51	.55	40	.255	13.7
17	33.25	50	.53	45	.....	13.8
18	35.00	50	.55	40	.100	15.2
19	36.50	50	.50	40	.175	15.0
20	30.00	51	.54	50	.110	14.5
21	35.50	51	.59	45	.200	14.0
22	.....	50	.56	45	.....	14.2
23	36.00	51	.60	40	.240	14.0
Average	34.40	50.6	.558	41.2	.179	14.1

TABLE 14.—*Churning data for pasteurized unripened cream—Creamery D.*

Churning No.	Fat in cream.	Churning temperature.	Acidity of cream as lactic acid.	Time required for churning.	Fat in buttermilk.	Water in butter.
	Per cent.	*°F.*	*Per cent.*	*Minutes.*	*Per cent.*	*Per cent.*
1	.....	51.00	0.14	19	0.160	13.6
2	.....	50.00	.14	25	.240	14.0
3	.....	49.00	.15	23	.400	.....
4	39.00	51.00	.13	22	.400	13.5
5	35.25	50.00	.24	14	.285	13.0
6	34.50	55.50	.13	30	.310	13.3
7	33.00	51.00	.14	30	.320	14.0
8	.....	51.00	.14	25	.325	15.0
9	40.25	52.00	.14	20	.290	13.9
10	40.50	52.00	.14	22	.170	14.9
11	38.50	52.00	.14	15	.400	15.9
12	35.00	51.00	.15	21	.215	15.6
13	32.25	51.00	.15	32	.230	15.5
15	.....	50.50	.15	35	.....	14.6
16	27.00	53.50	.14	17	.380	15.0
17	38.25	54.00	.15	23	.510	15.9
18	40.50	51.00	.....	32	.190	15.4
19	39.00	.....	.15	38	.120	14.3
20	35.50	56.00	.14	17	.220	15.7
Average	36.30	50.75	.142	24.2	.287	14.6

It will be noticed that the fat is higher in the buttermilk from the pasteurized unripened cream than in that from the raw cream or from the pasteurized ripened cream. This can be reduced by lowering the churning temperature, with, however, an increased tendency toward wavy or mottled butter. When sweet cream is churned without the addition of a starter the amount of buttermilk is reduced until the total loss of fat approximates that in buttermilk from an equal amount of butter made from ripened cream.

This butter was packed in May and the early part of June, and was scored before going into storage. The storage was arranged as with the previous lot. It was removed from storage late in January and scored as before by Mr. Joslin and a representative of the butter company. Nearly all of this butter was of good quality when fresh and would have been selected for storage. The scores before and after storage are given in Tables 15, 16, and 17, and are summarized in Table 18.

TABLE 15.—*Scores before and after storage of butter made from raw ripened cream—Creamery D.*

Churning No.	Score of fresh butter.	Comments.	Storage temperature.	Score after storage.	Comments.
			° F.		
1	93½	Oily	0	92	Trifle storage.
			10	89	Strong storage.
			20	90	Do.
2	94	Good butter	0	92½	Trifle storage.
			10	91	Do.
3	94	.....do	0	92½	Do.
			10	90	Strong storage.
4	94	.....do	0	92	Trifle storage.
			10	90	Do.
			20	89	Strong storage.
5	93	Coarse, oily	0	92	Trifle storage.
			10	89	Will go fishy, sour.
6	93½	Trifle oily	0	91½	Trifle storage.
			10	89	Strong storage.
7	93½	Trifle sour	0	92½	Trifle storage.
			10	89	Strong storage.
			20	90	Strong storage, oily.
8	94	Good clean butter	0	92½	Trifle storage.
			10	90	Strong storage.
9	94	Good butter	0	92½	Trifle storage.
			10	89	Strong storage.
			0	92½	Trifle storage.
10	94	.....do	10	88	Strong storage, unclean.
			20	91	Trifle storage.
11	93½	Not quite clean	0	92	Do.
			10	89	Strong storage.
12	93½	Trifle heated, greasy	0	92	
			10	88	Trifle storage.
			0	92½	Do.
13	94	Good butter	10	90	Fairly sweet, but strong storage.
			20	91	Trifle storage.
14	94	.....do	0	92	Do.
			10	90	Strong storage.
			0	91	Trifle storage.
15	93	Trifle metallic, will go fishy	10	88	Unclean, strong storage.
			20	89	Strong storage.
16	94	Good butter	0	92	Trifle storage.
			10	90	Strong storage.
17	93½	Trifle oily	0	92	Trifle storage.
			10	90	Strong storage.
18	93	Trifle unclean	0	91	Unclean, trifle storage.
			10	90	Strong storage.
			0	91	Unclean, trifle storage.
19	92½	Oily, will go fishy	10	90	Strong storage.
			20	89	Do.
20	93	Sour and oily	0	90	Unclean, trifle storage.
			10	90	Strong storage.
			0	91	Unclean, trifle storage.
21	93	Sour	10	90	Strong storage.
			20	90	Do.

TABLE 16.—*Scores before and after storage of butter made from pasteurized ripened cream—Creamery E.*

Churning No.	Score of fresh butter.	Comments.	Storage temperature.	Score after storage.	Comments.
			° F.		
E 1	94	Good, trifle oily	0	91½	Trifle storage.
			10	90	Do.
			20	91	Do.
2	94	High acid	0	92	Do.
			10	89	Going fishy, storage.
			20	90	Storage.
3	94	High acid, but clean	0	92	Trifle storage.
			10	89	Going fishy, storage.
			20	90	Storage.
4	93½	Trifle coarse salt for storage	0	91	Trifle oily and uncleau.
			10	90	Storage.
			20	91	Trifle storage.
5	93½	Oily or heated	0	92½	Do.
			10	91	Do.
			20	90	Storage.
6	93½	Trifle sour and oily, has been trifle heated.	0	92	Trifle storage.
			10	91	Do.
7	94	Not so oily	0	92	Do.
			10	92	Do.
			0	92½	Do.
8	93½	Trifle sour and oily	10	91	Do.
			20	91	Do.
			0	91	Do.
9	93½	Trifle oily	10	91	Trifle storage, oily.
			0	92½	Trifle storage.
10	94	Good butter, oily	10	88	Fishy.
			0	92½	Trifle storage.
11	94	Clean	10	92	Do.
			20	91	Do.
			0	91	Do.
12	94	Clean, just trifle oily	10	91	Trifle storage, oily.
			0	92	Trifle storage.
13	93	Metallic	10	91	Do.
			0	92	Do.
14	93	.....do	10	88	Fishy.
			20	90	Storage.
			0	92	Trifle storage.
15	92½	Coarse, metallic	10	90	Storage flavor.
			0	91½	Trifle storage, oily.
16	93	Sour and coarse, briny	10	91	Unclean, storage.
			0	91	Trifle storage, oily.
17	93	Sour and coarse	10	91	Trifle storage.
			20	89	Trifle storage, mottled.
18	93½	Fairly clean, good starter aroma.	0	92	Trifle storage.
			10	88	Fishy.
			0	91	Trifle storage.
19	94	Coarse salt	10	88	Fishy.
			20	86	Do.
			0	92	Trifle storage.
20	94	Good butter	10	89	Strong storage.
			0	92	Trifle storage.
21	93½	On metallic order	10	89	Strong storage.
			0	91	Trifle storage.
22	93½	Oily	10	89	Strong storage.
			20	87	Fishy.
			0	91	Trifle storage, mottled.
23	92½	Oily, wavy	10	89	Strong storage.

TABLE 17.—*Scores before and after storage of butter made from pasteurized unripened cream—Creamery D.*

Churning No.	Score of fresh butter.	Comments.	Storage temperature.	Score after storage.	Comments.
			°F.		
E 1	94½	Clean and sweet	0	94	Fine butter.
			10	93½	Sweet and clean.
			20	93	Do.
2	94	Heated, trifle oily	0	94	Do.
			10	93½	Do.
			20	93	Do.
3	94½	Good butter, clean	0	94	Fine butter.
			10	94	Do.
			20	93	Sweet and clean.
4	94½	Clean and sweet	0	93½	Fine butter.
			10	92½	Sweet and clean.
			20	93	Do.
5	95	Rich	0	94	Fine butter.
			10	93½	Sweet and clean.
6	94½	Clean and sweet	0	94	Fine butter.
			10	93½	Sweet and clean.
			0	94	Fine butter.
7	94½	Good butter	10	93½	Sweet and clean.
			20	92	Trifle unclean.
8	94	Trifle corded—mealy flavor	0	93½	Fine butter.
			10	93½	Sweet and clean.
			0	94	Fine butter.
9	94½	Good butter	10	93½	Sweet and clean.
			20	93	Good butter.
10	95	O. K., fine butter	0	94	Fine butter.
			10	93	Sweet and clean.
11	95	.....do	0	94	Fine butter.
			10	93½	Sweet and clean.
12	95	.....do	0	94	Fine butter.
			10	93	Sweet and clean.
13	95	.....do	0	94	Fine butter.
			10	93½	Sweet and clean.
			0	94½	Fine butter.
14	95	Good butter	10	94	Sweet and clean.
			20	93	Good butter.
15	95	Clean	0	94½	Fine butter.
			10	93½	Sweet and clean.
			0	94½	Fine butter.
16	94½	Trifle coarse	10	93½	Sweet and clean.
			20	93	Good butter.
17	95	Good butter	0	95	Fine butter.
			10	94	Do.
18	94	Oily	0	95	Do.
			10	94	Do.
19	94	Fairly clean and sweet	0	95	Do.
			10	94	Do.

TABLE 18.—*Average scores of Tables 15, 16, and 17—Creameries D and E.*

Character of cream.	Number of churnings.	Average score of fresh butter.	Storage temperature.	Number of tubs scored.	Average score after storage.
			°F.		
Raw ripened cream	21	93.55	0	21	91.86
			10	21	89 48
			20	8	89.88
Pasteurized ripened cream	23	93.52	0	23	91 74
			10	23	89 91
			20	11	89 64
Pasteurized unripened cream	19	94.61	0	19	94 18
			10	19	93 16
			20	8	92.88

For convenience of comparison the results of the scoring are arranged graphically in figures 2, 3, and 4. These curves are ar-

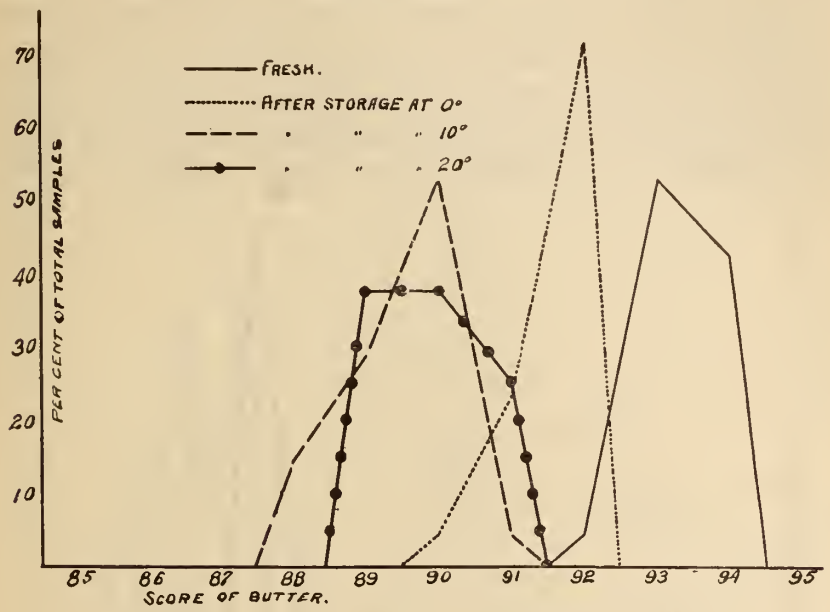

FIG. 2.—Distribution of butter scores before and after storage—Raw-cream butter.

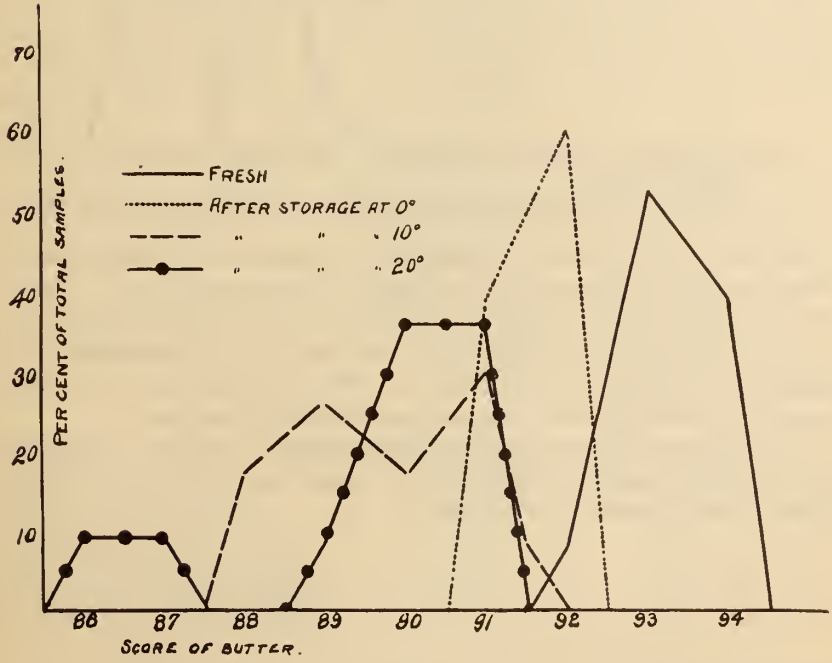

FIG. 3.—Distribution of butter scores before and after storage—Pasteurized ripened-cream butter.

ranged to show the relative proportion of the total amount given a certain score. For instance, of the butter made from pasteurized

cream 52 per cent was scored 93 or 93½ when fresh and 39 per cent was scored 94 or 94½. After storage at 0° F. 60 per cent was scored 92 or 92½. This arrangement shows little difference in the keeping quality of the butter made from raw cream and from pasteurized ripened cream. There is a somewhat wider range of scores in the butter made from the pasteurized ripened cream, due, evidently, to the occurrence of fishy flavor in that made from the raw cream. The superior keeping quality of the sweet-cream butter is evident in

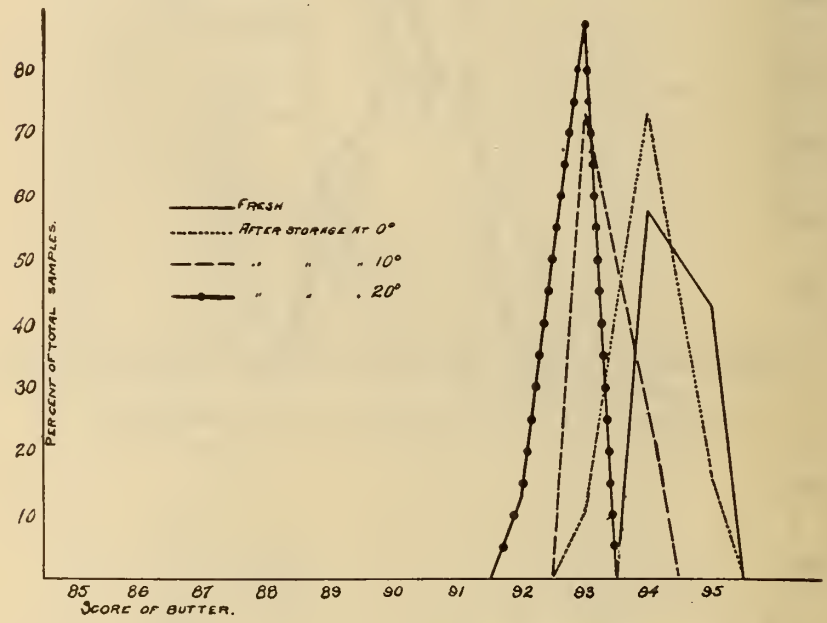

FIG. 4.—Distribution of butter scores before and after storage—Pasteurized unripened-cream butter.

its uniformity, the slight change from its original condition, and the almost complete absence of the usual cold-storage flavors. This is true not only of the butter stored at the commercial temperature, but in a lesser degree of that held at 10° and 20° F., which represent conditions that would tend to bring out defects and increase the difference between butters of good and poor keeping qualities.

This butter was made under conditions which could be duplicated by any dealer, public institution, or other large consumer wishing butter made expressly for storage.

THE INFLUENCE OF STORAGE TEMPERATURE ON CHANGES IN BUTTER.

The influence of temperature on the changes in storage butter is evidently a retardation of the rate of change, with a small but not determinative influence on the kind of flavor that develops. A certain state of deterioration may be reached in three weeks at 32° F. or three months at 0° F. The kind of flavor that develops in the butter is determined almost entirely before it goes into storage, but there are certain flavors more frequently observed in storage butter than under other circumstances. There is almost always a complication of flavors and probably some sort of sequence of flavors; that is to say, one flavor may develop into another, and this in course of time into a third. The temperature of storage doubtless retards this transition, and the holding of the butter for some time at one stage makes certain flavors evident which at a higher temperature would be obscured by the rapid change.

The results on various lots of butter reported in an earlier bulletin [1] of this division showed small difference between butter stored at −10° F. and 10° F., but a marked difference between the butter stored at 10° and 32° F. In the work reported in the present paper duplicate tubs were stored at 0°, 10°, and 20° F., partly to determine if there is much gained in the use of the lower temperature, but more especially to bring out at the higher temperatures the defects in the butter. A butter that holds up well at 0° but goes off flavor at 10° or 20° would probably deteriorate more rapidly after coming out of storage at 0°.

The differences in the rate of change at different temperatures are perhaps best expressed by showing the average loss in points as compared with the score of the fresh butter. Arranged in this way, the various lots of experimental butter show deterioration as follows:

TABLE 19.—*Average deterioration of butter after storage at various temperatures.*

Kind of butter.	Points lost after storage.		
	Stored at 0° F.	Stored at 10° F.	Stored at 20° F.
	Points.	*Points.*	*Points.*
Raw-cream butter—Creamery A	5.0	5.3	5.8
Raw-cream butter—Creamery D	1.7	4.1	3.3
Raw-cream butter—All samples	3.2	4.6	4.8
Pasteurized ripened cream—Creamery B	2.2	3.0	5.1
Pasteurized ripened cream—Creamery E	1.7	3.6	4.0
Pasteurized ripened cream—All samples	2.0	3.3	4.6
Pasteurized unripened cream—Creamery C	.6	1.0	1.5
Pasteurized unripened cream—Creamery D	.4	1.0	1.6
Pasteurized unripened cream—All samples	.5	1.0	1.6

[1] Gray, C. E., and McKay, G. L. The keeping qualities of butter made under different conditions and stored at different temperatures. With remarks on the scoring of the butter. U. S. Department of Agriculture, Bureau of Animal Industry, Bulletin 84. Washington, 1906.

The relation of the score after storage at the various temperatures to the score of the fresh butter is also shown in figure 5.

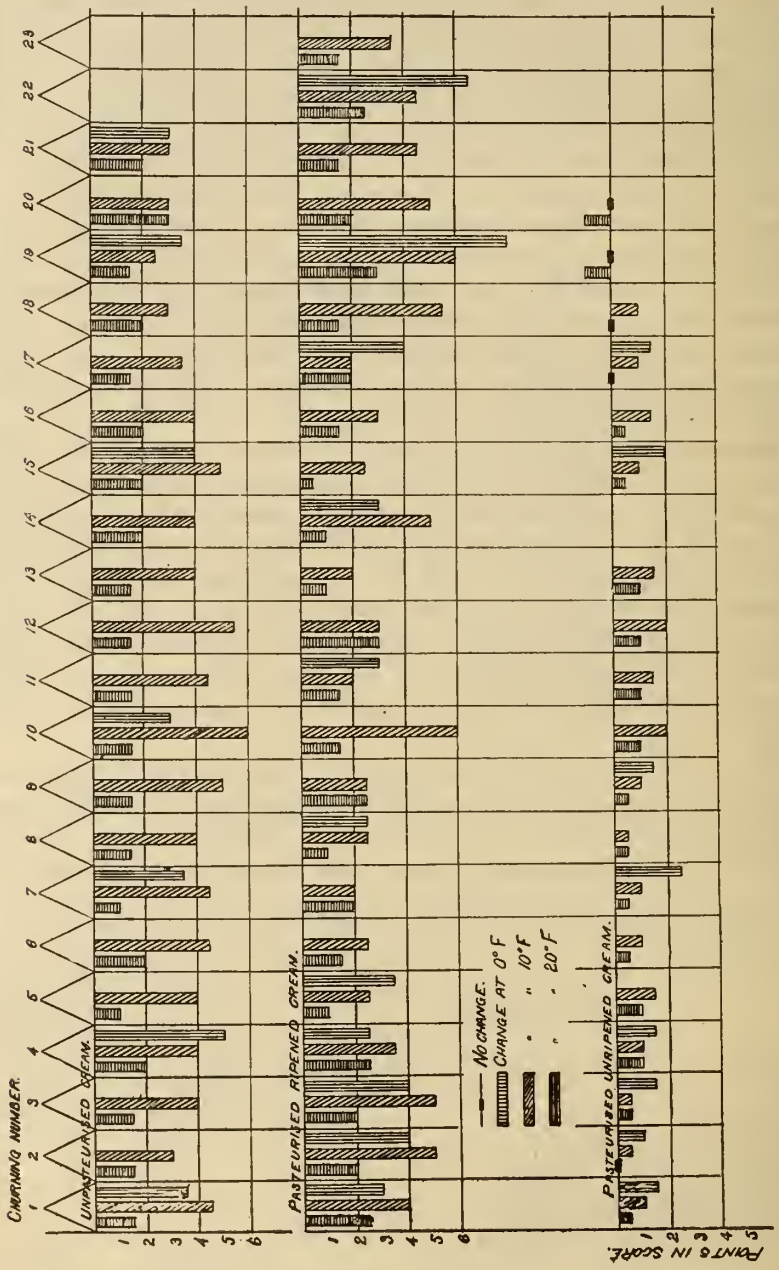

FIG. 5.—Changes in butter scores after storage at various temperatures.

The amount of deterioration as indicated by the differences in the scores before and after storage is in a general way directly propor-

tioned to the temperature of storage. The difference in the scores at 0° and at 10° is sufficient to warrant the use of the lower temperature even for butter of the best keeping quality. The striking thing in the table is the relative rate of change in butter made by the different methods. There was slightly less change in the pasteurized ripened-cream butter than in the raw-cream butter, but the change in the pasteurized ripened-cream butter stored at 0° F. was four times as great as that in the pasteurized sweet-cream butter at the same temperature, and the difference at the higher temperatures was nearly as great. Even at 20° F. the deterioration of the sweet-cream butter was comparatively slight, indicating that this butter would retain its flavor well after removal from storage.

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